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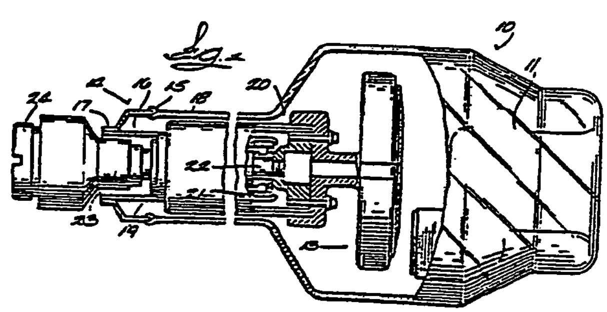
(54) **X-ray tube having a unitary target, stem and rotor hub.**

(57) An x-ray tube target element in which a target disk portion, a stem portion and a base portion are integral. The elements are composed, alternatively, of metals frequently used for target disks alone or of graphite. A layer of an alloy, such as tungsten-rhenium, disposed circularly on a face of the target disk substrate constitutes the focal track of the target. The base of the element is adapted for coupling it directly to the anode rotor assembly.



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X-RAY TUBE HAVING A UNITARY TARGET, STEM AND ROTOR HUB

Background of the Invention

This invention relates to rotating anode x-ray tubes.

Conventional rotating anode x-ray tubes comprise a cylindrical rotor sleeve which is mounted on bearings within the tube envelope and rotated by magnetic induction. The rotating x-ray target disks, variously comprised of tungsten, molybdenum, rhenium or alloys thereof or other refractory material such as graphite, is fastened to a stem, the stem is fastened to a rotor hub and the rotor hub is fastened to a bearing hub and to the rotor sleeve. It is desirable to make the stem of a relatively low heat conducting material such as columbium to minimize the amount of heat that is conducted from the target to the rotor bearings. Good design practice calls for diverting as much as possible of the conducted heat into the rotor sleeve which usually has a high thermal emissivity coating for inducing radiation of hear to the oil in a casing which surrounds the x-ray tube envelope. Much of the heat from the target is, of course, radiated directly to the oil.

One of the problems with heavy metal targets which are attached to a stem with a nut or by swaging the stem is that the target has a tendency to loosen and wobble and turn on the stem due to the high torque associated with rapid rotational acceleration and deceleration of the target disk. Similar problems arise in rotating anode x-ray tubes that use graphite targets which are fastened to a stem and the stem is fastened to

the rotor. Moreover, the good thermal emissivity characteristic of the graphite target is partly negated by having a metal stem in the conductive path to the rotor and its bearings. Graphite is, however, a desirable target material since it not only has high thermal emmissivity, approaching that of a theoretical black body, but it also has low mass which means it can be accelerated to maximum rotational speed in a shorter time and with less torque than a metal target. In most rotating anode tubes, the x-ray target is accelerated from rest to 10,000 rpm in less than two seconds and in some cases stopped just as abruptly after an x-ray exposure has been made. During use, the body of the target may be in the temperature range of 1100°C to 1350°C, the surface that provides the focal track may reach 2000°C, and the focal spot may approach 3000°C. Thus, there are substantial thermal differentials which must be contended with in determining how a target should be mounted to the rotor.

Summary of the Invention

In accordance with the invention, problems which result from having a metal or graphite target mounted on a stem made of a different material and having the stem attached to the x-ray tube rotor are minimized by using a target element wherein the target body, stem portion and rotor attachment hub are unitary.

A more detailed description of a unitary target element based on refractory metal or, alternatively, graphite will now be set forth in reference to the drawing.

Description of the Drawing

FIGURE 1 shows a typical rotating anode x-ray tube in which the new unitary target is used;

FIGURE 2 is an enlarged fragmentary and partially sectional view of the x-ray tube rotor to which the new unitary target is attached;

FIGURE 3 is a view of the face of the unitary target element on which the focused electron beam impinges to produce x-rays, and

FIGURE 4 is an alternative embodiment of a graphite body target element and a fragmentary section of a rotor to which it is mounted.

Description of a Preferred Embodiment

FIGURE 1 shows a typical rotating anode x-ray tube in which the new unitary target element is used. The tube comprises a glass envelope 10 having a cathode structure 11 sealed into one end. The electrical conductors leading to cathode structure 11 are not shown since they are well known. Cathode structure 11 has an electron beam focusing cup 12. The new unitary target element comprised of a target body, stem and attachment base or hub is designated generally by the reference numeral 13.

The left end of glass envelope 10 in FIGURE 1 has a metal ferrule 14 sealed into it along a glass-to-metal joint marked 15. A metal tubular element 16 is welded at one of its ends to ferrule 14 along a weld joint marked 17. Tubular element 16 extends axially through the neck 18 of envelope 10 and joins with a hollow coaxial cylindrical element 19 in which the outer race 21 of one of the bearings that is visible is retained. A shaft 22 has the inner race of this bearing fastened to it. The rotor sleeve 20 and unitary target 13 are fastened to the shaft for rotating with it.

Referring further to FIGURE 1, metal tube 16 is hermetically sealed to the bearing retaining cylinder 19. An adapter 23 is joined with cylinder 19 to provide electrical continuity through the tube. It will be evident that the anode-to-cathode load current will flow through the bearings. Adapter 23 has a slotted screw 24 which is used for making an electrical connection to the tube and for supporting it in its casing which is

not shown.

Referring to FIGURE 2, one may see that the inner race 25 or one of the ball bearings is clamped on shaft 22 by means of a bearing hub 26 which turns onto the threaded end 27 of the shaft. It is desirable to tack weld bearing hub 26 to the threaded end 27 of the shaft at a few points such as the one marked 28 so there is no chance of the bearing hub unscrewing from the shaft when the rotor is magnetically braked as is the case when an x-ray exposure has been completed. It is desirable to make bearing hub 26 out of a metal which has low thermal conductivity to minimize heat conduction from the unitary target element 13 to the bearings. Nickel-based alloys fulfill the low conductivity requirement. Several suitable alloys are mentioned in U.S. Patent No. 4,187,442 which is owned by the assignee of this application. In any case, bearing hub 26 should have the thinnest cross section permissable commensurate with strength requirements to inhibit flow of heat from the unitary target element 13 to the bearings. Hub 26 in the illustrated design has four radially extending pads such as those marked 29 and 30 for interfacing with unitary target element 13. The joint between the pads and the target element is marked 31. The end faces of the pads at the joint 31 are machined truly perpendicular to the axes of the shaft and bearing hub and the inside face of the target element is matched to the pads to assure there is not run-out, that is, that the axes of the shaft and target body are in line. The pads are notched out as indicated by the numeral 32 to further inhibit heat flow to the bearing hub and influencing more of the heat to flow to the rotor sleeve 20.

The unitary target element 13 is depicted as being made of graphite. It comprises a disk-like body 40 with an integral graphite neck or stem 41 and a connecting base or hub 42. In this design, the hub is recessed at its inner end such that an axially extending portion 43

is formed. Portion 43 is provided with an internal thread 44 which turns onto a complementary external thread on rotor sleeve 20. Rotor sleeve 20 is a laminated structure comprised of an inner sleeve of steel 20' and an outer sleeve 20". Thread 44 is cut in the copper layer. Axially extending portion 43 of target element 40 has several radially extending threaded holes 45 in thich there are socket-headed set screws 46 which pass through the laminated sleeve and assist in preventing the unitary target element 13 from turning off of rotor sleeve 20 as a result of rotational acceleration or deceleration. The internal and external threads on portion 43 of the target body and on the copper rotor sleeve can be mated loosely to provide minor free-play for enabling the rotor hub pads to meet the inside face of target element portion squarely and thereby avoid possible run-out. The rotor hub or base 42 is secured to bearing hub 26 by means of screws such as the one marked 47 which thread into the bearing hub and pass through some axially extending holes 48 in the target element hub 42. Large area washers 49 are interposed between the socket heads of screws 47 to distribute the compressive force which results from tightening the screws.

The illustrated embodiment has an axially extending hole 50 which reduces the cross section of stem portion 41 and further inhibits heat conduction from target body 40 to the hub and, hence, to the rotor bearings. As indicated earlier, an objective is to direct as much heat to the rotor sleeve 20 as possible for it to be radiated from the sleeve. By having the hub portion 42 of the target element external to the rotor sleeve, advantage can be taken of the superior thermal emissivity of graphite over a greater length or peripheral area of the target element. It will be noted that all corners of the target element are rounded to relieve stress since graphite is most vulnerable to fracturing

wherever it is notched or has sharp corners.

One of the merits of the unitary graphite target is that it can be machined accurately from a solid cylinder of graphite. Moreover, since the target body 40, the stem portion 41 and hub portion 42 are unitary, these three portions can be machined in the same machine set-up so that the lack of concentricity or run-outs between the hub, stem and target body when made as separable parts in the traditional fashion can be minimized.

The margin of the front of the target is beveled in the annular region marked 51 to provide the surface on which the electron beam impinges to produce x-rays. Surface 51 has a thin annular refractory metal layer 52 deposited on it and constitutes the focal track on which the electron beam impinges. Focal track 52 is customarily comprised of a metal that has good x-ray emitting properties such as tungsten, tungsten-rhenium, tungsten-iron, or molybdenum by way of example. The focal track may be applied to the graphite target after finish machining by any of the suitable known deposition processes such as electro-deposition, chemical vapor deposition or other coating process which do not have to be described in detail since they are known to those skilled in the art of x-ray tube design.

Despite the advantages of graphite having low density for reducing bearing load and making acceleration and deceleration easier and faster, having high emissivity for permitting better radiation with resultant faster cooling and having lower thermal conductivity than most metals for reducing the bearing heating problem, use of graphite targets has been restricted to low energy x-ray tubes because graphite has a propensity to dust off and cause electrical breakdown in x-ray tubes. Hence, to get all of the advantages of the unitary target element described herein, it is necessary to treat the surface of the graphite in a menner which will inhibit dusting off. A graphite surface treatment for achieving this

objective uses pyrolytic carbon infiltrated graphite.

Many of the advantages, the basic concept of having a unitary target body, stem and attachment base or rotor hub can also be implemented with an all-metal version of the target element. Applicants have made unitary targets of metal as well as graphite. One embodiment, not shown, of a unitary target element 13 made of all metal has the same configuration as the target element 13 which is shown and cross hatched in a manner indicative of graphite. Rather than illustrate the target element twice, the reader is asked to assume that the alternative target element is all metal. One version of the all-metal target element used molybdenum for the body 40, stem 41 and attachment base or hub 42. The focal track layer is composed of tungsten-rhenium alloy than can be deposited by any one of the methods mentioned before as being applicable to graphite. The all-metal unitary target may also be composed of a tungsten-rhenium alloy focal track layer on a molybdenum or molybdenum alloy substrate or body, that has been formed by pressing powdered metal and then sintering and forging it as a composite with the layer and body together. Of course, the unitary target element may be made entirely of molybdenum or tungsten or their alloys and the focal track layer 52 may be omitted for some tubes. It is desirable to retain the central hole 50 in the all-metal target to reduce the heat conducting cross section of the stem portion 41. However, with an all-metal unitary target element in particular, heat conduction through the stem portion 41 may be reduced by reducing the diameter of the stem portion and dispensing with the hole. It should be recognized too that central hole 50 is not indispensible to obtaining the main advantages of the unitary graphite target.

The unitary all-metal target including the focal

track alloy can be produced by conventional powder metallurgy techniques involving preparation of a preform by pressing metal particles as close as possible to the desired finished size and shape using either a split die or hot or cold isostatic pressing which is known to those skilled in the art. The pressed preform is then sintered in a hydrogen atmosphere or vacuum at temperatures and times appropriate for the materials involved. The sintered part is subsequently hot forged, as is done in making traditional target disks in order to achieve maximum density of the part, the necessary mechanical properties and to minimize machining.

FIGURE 4 shows an alternative unitary graphite target element 60 that is designed for being mounted on the x-ray tube rotor in a different manner than the previously discussed embodiments. The unitary target element comprises a disk portion 61 having an integral neck or stem portion 62 and an integral base portion 63. The annular beveled edge on the face of the target is provided with a thin layer of refractory material 64 on which the electron beam of the x-ray tube impinges to produce x-radiation. This layer may be composed of any of the materials mentioned earlier and the layer may even be omitted in some cases.

Target body 60 in the FIGURE 4 embodiment can be made by turning it as with a lathe from a graphite cylinder. Base portion 63 is provided with an external thread 65 which is turned into a mating thread that is internal to an axially extending hollow cylinder 66. The cylinder is an integral part of a rotor hub which is generally designated by the numer 67. Target element base 63 is prevented from turning in hub cylinder 66 by means of several cup-point Allen set screws such as the one marked 68. The threads 65 can mate somewhat loosely to allow the end of cylinder 66 and the end face of the shoulder 69 on the ste . portion 62 of the target to mate squarely. This enhances heat transfer and has as its

objective minimizing run-out.

Rotor hub 67 is provided with an axially extending cylindrical portion 70 to which the inside steel layer 71 is brazed in the joint area 72. There should be brazing metal in the joint 73 between the rotor hub and the ends of the steel sleeve 71 and the copper rotor sleeve 74 as well. This enhances heat conduction from the hub 67 to the rotor. The rotor hub 67 is desirably made of a relatively good heat conducting material having expansion properties compatible with graphite. TZM alloy is an example of a metal that is suitable for the rotor hub.

The rotor is mounted to the externally threaded end 75 of the x-ray tube shaft 76 by means of a bearing hub 77. Several screws such as the one marked 78 secure the bearing hub 67 squarely against the end face of the rotor hub. A nut 79 presses against the rotor hub to prevent it from turning on thread 75 of the shaft. It is preferable to stake the nut at several places to assure it will not loosen. The rotor hub has a projection 84 which bears against the inner race 80 or a ball bearing whose outer race 81 is anchored in the end of a cylindrical member 82 which is, in turn, fixedly mounted within the x-ray tube envelope. It is desirable to make rotor hub 77 or a relatively poor conducting metal such as a nickel alloy as in the previously discussed embodiment.

The structures described above for mounting the new unitary target element on an x-ray tube rotor are intended to be illustrative rather than exclusive. Various manufacturers will choose a mounting scheme that is appropriate to their particular rotor design. In any case, however, it is considered desirable to choose mounting materials that inhibit the flow of heat from the target element to the bearing structure and direct as much heat as possible to the outer rotor sleeve 20 for radiation to the cooling oil, not shown, which surrounds

the x-ray tube envelope. Since the unitary target element must be fired at high temperature to degas it, prior to installation in an x-ray tube, it is desirable to select a mounting scheme which permits the target element to be fired by itself, that is, without being attached to rotor parts which might not be able to tolerate the high temperatures to which the target element must be exposed.

CLAIMS

1. A unitary target element (13, 60) for an x-ray tube having a rotor assembly (20), the element characterized by

a circular target body portion (40, 61), a stem portion (41,62) integral with and extending coaxially from said body, and a base portion (42,63) integral with said stem and spaced from the body portion for mounting the element to said rotor assembly.

2. The unitary target element defined in Claim 1 characterized in that the base portion is circular and extends radially and integrally from said stem portion and is spaced from said target body, said rotor assembly having a circular part and said base portion having a circular recess (43) on a side remote from target body for fitting (44) said base portion on said rotor.

3. The unitary target element defined in Claim 1 characterized in that the base portion of the integral element has an external thread (65) for coupling it to said rotor.

4. The target element as defined in any one of claims 1, 2 or 3 characterized in that the integral target body portion, stem portion and base portion are composed of graphite.

5. The target element as defined in any of claims 1, 2 or 3 characterized in that the target body portion, stem portion and base portion are composed of a metal selected from the group consisting of tungsten and molybdenum and alloys of tungsten and molybdenum.

6. The unitary target as defined in any one of claims 1, 2 or 3 characterized in that the stem portion has an axially extending hold (50) for reducing its cross sectional area to thereby reduce heat conduction from said target body portion to said rotor.

7. The unitary target element as defined in claim 1 characterized in that the circular target body portion, stem portion and base portion for mounting are composed of graphite and a face of said target body portion opposite of the stem is beveled to define an annular focal track region (52), and at least a portion of said region has a circular layer of tungsten-rhenium alloy bonded to it.

8. The unitary target as defined in claim 1 characterized in that the circular target body portion, stem portion and base portion are composed of molybdenum and a face of said target body opposite of said stem portion is beveled to define an annular focal track region (52) and at least a portion of said region has a circular layer of tungsten-rhenium alloy bonded to it.

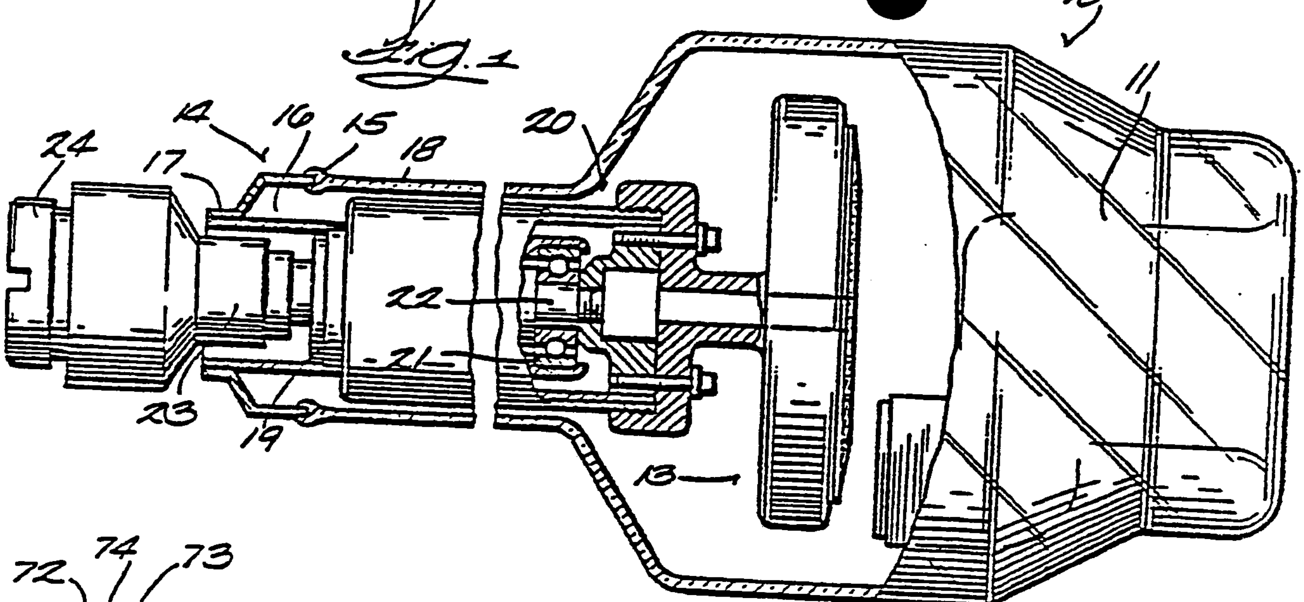

Fig. 1

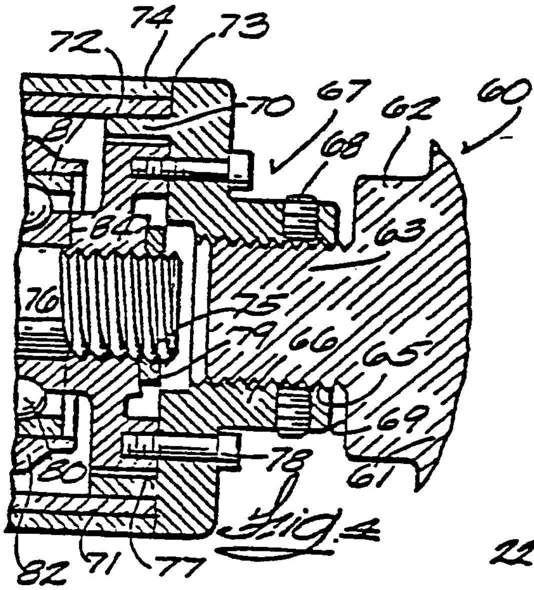

Fig. 4

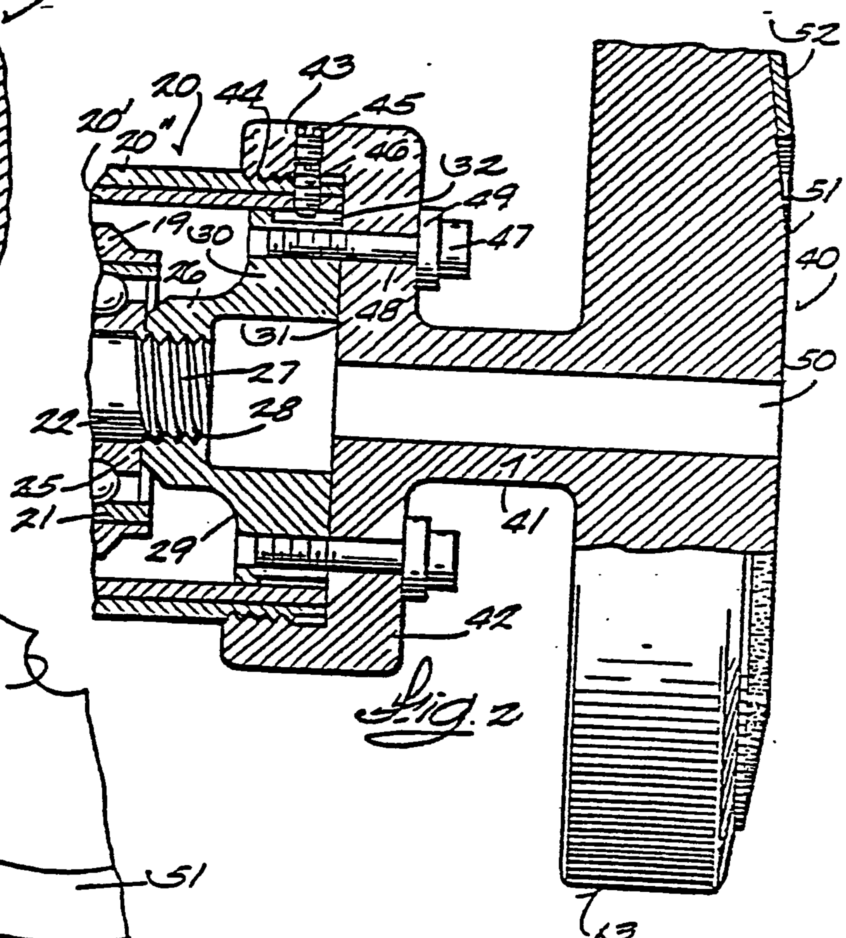

Fig. 2

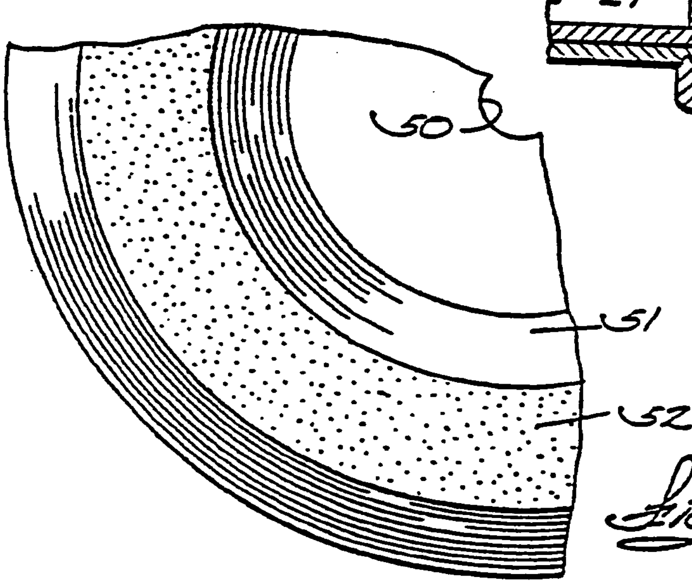

Fig. 3

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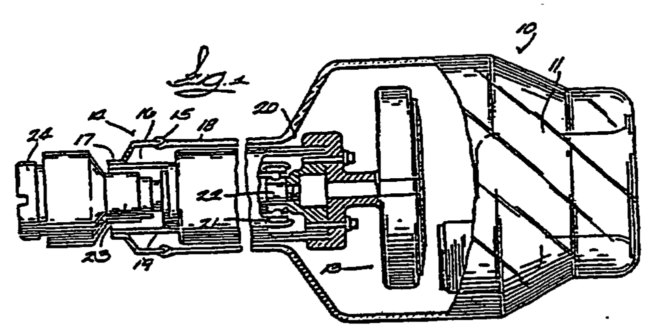

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EUROPEAN SEARCH REPORT

Application number

EP 81 10 9788

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. [3])
A	FR-A-2 225 839 (GENERAL ELECTRIC) *Page 12, lines 1-30, fig. 8* -----	1	H 01 J 35/10

TECHNICAL FIELDS SEARCHED (Int. Cl. [3])

H 01 J 35/10
H 01 J 35/26
H 01 J 35/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-04-1982	ARMITANO-GRIVEL M.

CATEGORY OF CITED DOCUMENTS

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